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Indian Standard

ELECTRICAL INSULATING MATERIALS — THERMAL ENDURANCE PROPERTIES

PART 5 AGEING OVENS

Section 2 Precision Ovens for Use Up to 300°C

ICS 17.220.99; 29.035.01

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Solid Electrical Insulating Materials and Insulating Systems Sectional Committee, ETD 02

NATIONAL FOREWORD

This Indian Standard (Part 5/Sec 2) which is identical with IEC 60216-4-2 : 2000 'Electrical insulating materials — Thermal endurance properties — Part 4-2: Ageing ovens — Precision ovens for use up to 300 °C' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Solid Electrical Insulating Materials and Insulating Systems Sectional Committee and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminology and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60216-1 : 1990 Guide for the determination of thermal endurance properties of electrical insulating materials — Part 1: General guidelines for ageing procedures and evaluation of test results	IS 8504 (Part 1) : 2012 Electrical insulating materials — Thermal endurance properties: Part 1 Ageing procedures and evaluation of test results (*second revision*)	Identical to IEC 60216-1 : 2001
IEC 60216-4-1 : 1990 Guide for the determination of thermal endurance properties of electrical insulating materials — Part 4: Ageing ovens — Section 1: Single-chamber ovens	IS 8504 (Part 5/Sec 1) : 2012 Electrical insulating materials — Thermal endurance properties: Part 5 Ageing ovens, Section 1 Single-chamber ovens	Identical to IEC 60216-4-1 : 2006

Only the English language text has been retained while adopting it in this Indian Standard and as such the page numbers given here are not the same as in the IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ELECTRICAL INSULATING MATERIALS — THERMAL ENDURANCE PROPERTIES

PART 5 AGEING OVENS

Section 2 Precision Ovens for Use Up to 300°C

1 Scope

This part of IEC 60216 covers minimum performance requirements for ventilated and electrically heated precision ovens for thermal endurance evaluation of electrical insulating materials and other appropriate applications. It covers ovens designed to operate over all or part of the temperature range from 20 K above room temperature up to 300 °C.

Two possible methods of achieving the required performance are described:

a) where the required performance is achieved by precise control of temperature in a simple single chamber oven, i.e. upgraded versions of ovens conforming to IEC 60216-4-1, and, otherwise,

b) where the required performance is achieved by utilizing a second chamber (iso-box), mounted within the chamber of a single-chamber oven, the purpose of which is to reduce the magnitude of any temperature changes to an acceptable level whilst maintaining the required levels of air change and circulation.

NOTE 1 Experience has shown that employment of an iso-box is an economical and practical means of meeting the requirements for a precision oven.

NOTE 2 It is recommended that a precision oven rather than a standard oven is used when the expected halving interval is less than 10 K (20 kh to 10 kh) in order to increase the precision of the measured temperature index and halving interval to a reasonable level.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60216. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60216 are encouraged to investigate the possibility of applying the most recent edition of the normative documents indicated below. For undated references, the latest editions of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60216-1:1990, *Guide for the determination of thermal endurance properties of electrical insulating materials – Part 1: General guidelines for ageing procedures and evaluation of test results*

IEC 60216-4-1:1990, *Guide for the determination of thermal endurance properties of electrical insulating materials – Part 4: Ageing ovens – Section 1: Single-chamber ovens*

3 Definitions

For the purpose of this part of IEC 60216, the following definitions apply.

3.1
rate of ventilation
number of air changes per hour in the exposure chamber at room temperature

3.2
exposure volume
that part of the space in the oven chamber (or within the iso-box, when used) where the temperature difference and temperature fluctuation do not exceed the specified limits

3.3
temperature fluctuation
maximum change in temperature at one point in the exposure volume over a period of 3 h

3.4
temperature difference
maximum difference of temperature between any two points in the exposure volume at any one time

3.5
global average temperature
average temperature, calculated from the results of determinations made over a period of approximately 3 h using nine sensors spaced throughout the exposure volume

NOTE The global average temperature is considered to be the initial effective global exposure temperature if the sensors are mounted in the same space that contains the specimens. The term "global exposure temperature" is frequently abbreviated to "exposure temperature".

3.6
global exposure temperature
temperature selected for ageing test specimens to obtain data for the determination of the effects of temperature on those specimens

3.7
standard oven
oven with an electrically heated and ventilated chamber and with the ability to maintain the exposure temperature in its exposure volume within the limits given in IEC 60216-4-1

3.8
precision oven
oven which meets the requirements of this standard

NOTE The limits for temperature difference and temperature fluctuation in the exposure volume given in this standard are tighter than those given in IEC 60216-4-1.

3.9
oven chamber
interior volume of the single-chamber oven providing the space for exposing test specimens or accommodating an iso-box

3.10
iso-box
metal box with a close-fitting door, mounted in the oven chamber and used in preference as the exposure chamber

3.11
ventilation
continuous passage of pre-heated air through the exposure chamber

3.12
temperature deviation
calculated difference in the exposure temperature from the intended value due to the combination of the temperature difference, temperature fluctuation and the error in the measurement of temperature

3.13
halving interval
difference between two exposure temperatures which causes the halving of the heat ageing period required to arrive at a certain agreed level of property change of the material under test (see IEC 60216-1)

4 Constructional requirements

4.1 General

The oven system shall be soundly constructed of suitable materials designed for continuous operation over the whole of the allowable temperature range.

All electrical and other ancillary fittings shall be readily accessible for maintenance purposes.

4.2 Mechanical requirements

4.2.1 Oven

The materials of construction of the oven chamber and the interior fittings shall be so chosen as to not influence the properties of the specimens.

NOTE 1 Aluminium alloys and stainless steel have been found suitable in many cases.

Attention should be given to ensure that the door to the oven chamber is provided with an efficient seal and that any gasket materials used do not influence the properties of the specimens.

The exposure chamber shall be provided with a supply of preheated ventilating air which shall be directed in such a manner as to produce turbulence throughout the chamber.

NOTE 2 Wherever possible, the supply should be continuously filtered, metered and monitored.

NOTE 3 Inlet and outlet vent fittings with dampers designed to allow adjustment of the rate of ventilation have been found to be satisfactory.

4.2.2 Iso-box

The construction shall be such that the requirements for temperature fluctuation and temperature difference are met throughout more than 50 % of the space inside the iso-box when it is mounted in any chosen oven. The rate of ventilation shall conform with the requirements.

NOTE Boxes made from aluminium alloy sheet have been found to be satisfactory.

The iso-box shall have a door which shall be close-fitting without any sealing gasket.

All air that enters the oven as ventilating air shall pass through the iso-box in such a manner as to produce turbulence.

4.3 Temperature control and indicator systems

The oven chamber (or iso-box, when used) shall be fitted with a minimum of two temperature sensors (numbered 1 and 2). Before installation, the sensors 1 and 2 shall be calibrated by reference to a suitable standard (sensor 3) to give a maximum measurement uncertainty within ±0,5 K. The difference in reading of the two sensors, as a function of temperature shall be recorded.

Sensor 3 shall have a maximum uncertainty of ±0,1 K.

Temperature sensor 1 shall be connected to a readout, mounted in a convenient manner, and used to indicate the chamber temperature on a continuous basis.

NOTE 1 The readout also allows early identification of any malfunction in the system.

Temperature sensor 2 shall be mounted as closely as possible to where the test specimens will be located. Its placement shall be well-defined and reproducible. It may be removed after the measurements.

An independent sensor may be used to control the temperature. The placing of that sensor shall be at the manufacturer's discretion. The control system shall have a drift rate of less than 1 K/year.

NOTE 2 The sensors may be of any type that meets the requirements (for example liquid-filled thermometer, resistance thermometer).

NOTE 3 Since the performance of thermocouples is less precise than filled thermometers and resistance systems, their use is not recommended for the measurement of temperature, although they may be found suitable for the measurement of temperature difference.

Where liquid-filled thermometers are used, care shall be taken to ensure that the immersion depth in use is the same as that used during calibration.

The oven shall be equipped with an excess temperature control device which shall be independent of the main temperature control system. It shall switch off the electrical heaters in the case where the actual temperature exceeds the intended temperature by a certain pre-set amount. The system shall also ensure that a warning light is switched on if the excess temperature device operates, and that the heaters are not started automatically again when the oven temperature has dropped below the set temperature value, but require a manual start after the warning light has been manually switched off.

5 Performance requirements

Where there is an expectation in practice that the test specimens and supports could occupy more than 25 % of the exposure volume, the manufacturer and supplier should agree with the user on whether dummy loads should be used during the assessment of performance.

5.1 Temperatures

It shall be possible to control the temperature of the exposure volume to within the limits of temperature difference and temperature fluctuation over the full range claimed by the manufacturer.

5.2 Maximum temperature difference

Within the exposure volume, the temperature difference shall not exceed ±0,5 K.

5.3 Maximum temperature fluctuation

Within the exposure volume, the temperature fluctuation shall not exceed ±0,5 K.

5.4 Maximum temperature deviation

Within the exposure volume, the temperature deviation shall not exceed ±2 K.

5.5 Type and rate of ventilation

Rates in the range 5 to 20 changes per hour shall be made available in the exposure chamber in such a manner as to produce turbulence.

Consideration shall be given to ensure adequate purity of the incoming air to minimize influences on the ageing behaviour.

When specified in the purchase contract, provision shall be made for the use of ventilating gases other than air.

5.6 Exposure volume

The exposure volume shall be sufficient to accommodate the test specimens. It shall not be less than 50 % of the volume of the oven chamber (or of the iso-box, if used).

NOTE Experience has shown that an exposure volume of 35 l to 70 l is generally found to be convenient.

6 Test methods and procedure

The size and shape of the exposure volume is determined from the results of a series of experimental determinations of temperature difference and temperature fluctuation, made using different placements of a series of temperature sensors at each of three temperatures and at the expected use rates of ventilation. These three temperatures shall be the minimum and maximum temperatures at which the oven is designed to operate, and one approximately mid-way between these two, for example 50 °C, 175 °C and 300 °C.

During all measurements of performance, the ambient temperature and the supply voltages to the oven shall be controlled to within the range stipulated by the manufacturer for the correct performance of the oven.

6.1 Temperature and related parameters

6.1.1 Practical aspects

The temperature of the oven chamber and, finally, of the exposure volume shall be determined using temperature sensor number 2.

For the determination of temperature difference and temperature fluctuation, place a series of temperature sensors (maximum diameter, 5 mm) in the oven chamber (iso-box, when used) under investigation, ensuring that

– one sensor is located within 25 mm of the centre of the chamber;
– one additional sensor is located (50 ± 10) mm distance from the walls in each of the eight corners of the chamber.

Conduction of heat from the temperature sensors shall be minimized by ensuring that there is a sufficient length of connecting wire inside the oven and that externally the wires are thermally insulated and maintained in essentially draught-free conditions.

NOTE In order to evaluate temperature difference and temperature fluctuation, if calibrated temperature sensors are not available, thermocouples made from the same spool of thermocouple wire and prepared in the same manner may be used provided that, when placed adjacent to one another in the testing chamber at the maximum operating temperature, they give values of temperature that do not differ by more than 0,2 K.

Set the level of ventilation at the manufacturer's stated minimum.

Allow the temperature of the chamber to stabilize.

Measure the temperature of the individual sensors to 0,1 K a sufficient number of times over a period of approximately 3 h to allow identification of any cyclic behaviour and permit determination of the maximum, minimum and mean temperatures of each temperature sensor over the measuring period.

6.1.2 Calculations

Temperature fluctuation (δT_1)

Inspect the data and calculate the maximum difference in temperature, recorded over a period of 3 h, for each of the nine sensors. Identify the largest of these differences, and record that as the "day 1 temperature fluctuation".

Temperature difference (δT_2)

Inspect the data and calculate the maximum temperature difference present in the exposure chamber at any one time during the period of 3 h. Record that as the "day 1 temperature difference".

6.1.3 Results

If the results meet the requirements for temperature difference and fluctuation, repeat the measurements every day for a period of five days.

Repeat the calculations for the remainder of the data and record the day 2, 3, 4 and 5 temperature differences. Select the largest of these day temperature differences and record as the (oven) temperature difference δT_1.

Repeat the calculations for the remainder of the data and record the day 2, 3, 4 and 5 temperature fluctuations. Select the maximum day temperature fluctuation and record as the (oven) temperature fluctuation, δT_2.

If the measured oven temperature difference and fluctuation levels fall within the requirements, the oven shall be said to conform with the requirements at the particular chamber temperature and ventilation level. The exposure volume is the space within the eight corner sensors.

If the results do not meet the requirements, reposition the sensors approximately 25 mm further from the walls and repeat the tests and calculations.

If the measured oven temperature difference and fluctuation levels fall within the requirements, the oven shall be said to conform with the requirements at the particular chamber temperature and ventilation level. The exposure volume is the space within the eight repositioned corner sensors.

Repeat the measurements at the other two chamber temperatures using appropriate ventilation rates to determine the exposure volume for these temperatures.

Temperature deviation (δT_d)

The temperature deviation δT_d shall be calculated in accordance with annex B, using the calculated value of temperature difference and temperature fluctuation, the difference between the readings of the temperature sensors 1 and 2 as determined from the initial calibration, and by reference to the exposure temperature as indicated by the readout from sensor 1 during long-term heat ageing experiments.

6.2 Rate of ventilation

Any adequate method may be used to determine the rate of ventilation if a metered supply is not used.

One procedure which is based on the measurement of the increase in power consumption required to maintain the temperature in the oven chamber with the vents open, over that required to maintain the exposure chamber at the same temperature with the vents closed is given in annex A.

The air supply and exhaust system shall be adjusted until the measured rate of ventilation meets the requirements.

NOTE The provision of dampers facilitates these adjustments.

7 Report

The supplier of the oven shall provide at least the following information:

- type and designation;
- range of supply voltage over which the oven conforms with this standard;
- maximum power consumption;
- range of ambient temperature over which the oven conforms with this standard;
- mass of the complete (empty) oven and external dimensions;
- range of exposure volume temperatures over which the requirements for temperature difference and temperature fluctuation conform with this standard;
- range of available ventilation rates;
- results of the tests described in clause 6.

8 Conditions of use and instructions for in-service monitoring by the user

8.1 Conditions of use

a) During use, the ambient temperature and the supply voltages shall be controlled within the range stipulated by the manufacturer for the correct performance of the oven.

b) Unless otherwise specified, the quality of the ventilating air shall be sufficient not to affect significantly the results. In cases where the results of tests are influenced by impurities in the ventilating medium, for example, water vapour, it shall be controlled and reported.

c) Where a number of ageing ovens are in use in a local area, care shall be taken to prevent cross-contamination of volatile components, i.e. ventilating air from one oven shall not come into contact with specimens in any other oven.

NOTE It is recommended that the exhaust from each oven be vented directly to outside atmosphere.

d) Precautions shall be taken to ensure that volatiles produced by the ageing process do not damage health or the environment.

e) Where significant levels of volatiles and/or degradation products are released during the ageing process, then due consideration shall be given in the product standard to the most suitable rate of ventilation to be applied.

f) During temperature exposure, no test specimen shall be stored outside of the exposure volume, and specimens shall only touch the supports and not touch each other.

8.2 Procedure

Prior to long-term heat ageing, the temperature in the oven chamber (or in the iso-box if used) shall be adjusted to the nominal exposure temperature as measured by temperature sensor 2 which shall be placed as close as possible to where the test specimens will be located. Its placement shall be well-defined and reproducible.

Where liquid-filled thermometers are used, care shall be taken to ensure that the immersion depth in use is the same as that used during calibration.

8.3 In-service monitoring

The following test on a loaded oven shall be made immediately before each ageing test.

NOTE These tests are to confirm that the loaded oven meets the requirements of this specification at the beginning of the ageing test. In the tests, the global exposure temperature and the temperature variation are determined.

Following the general procedure given in 6.1,

a) place a series of eight temperature sensors within but close to the periphery of the mounted specimens in the exposure volume under evaluation;

b) raise the oven temperature to the planned figure and allow to stabilize;

c) determine the global average temperature (which is assumed to be the initial exposure temperature) and the temperature variation over a period of approximately 3 h using data from the eight sensors in addition to that from sensor 2.

If the results do not meet the requirements, terminate the ageing programme and re-organize the test specimen mounting arrangements or otherwise adjust the equipment until, on repeating the tests, conformance is confirmed.

If it is desired to estimate a more precise exposure temperature than that determined in the test above, then a long-term average of the temperature measured using sensor 2 should be calculated.

Annex A
(informative)

Test method to determine the rate of ventilation

Any other method of equivalent accuracy may be used.

A.1 Sealed oven

The oven shall be properly sealed, including vent ports, door, temperature sensor port and blower shaft or complete blower, if applicable. A watt-hour meter with an accuracy of ±1 Wh or better shall be connected into the oven power supply line and the oven energized. An appropriate control temperature shall be chosen and set.

After the oven temperature has stabilized, the following measurements shall be taken:

– room temperature at a point 2 m distance from any significant thermal source, at least 1 m from any solid object and at about the same level as that of the oven inlet vent;

– electrical energy consumed over a period of time of at least 1 h to within ±2 Wh, with the corresponding time measured to within ±3 s.

A.2 Ventilated oven

After all seals being removed, the size of the damper for the inlet vent shall be estimated to give the required rate of ventilation. Again, after the oven temperature has stabilized, consumption of electrical energy shall be determined as under clause A.1 for the same period of time.

A.3 Calculation

The rate of ventilation is calculated by the following equation:

$$N = [10(P_2 - P_1)T_a]/V_o(T - T_a)$$

where

N is the rate of ventilation;

P_1 is the mean power consumption, in watts, of the non-ventilated oven, obtained by dividing the energy consumption E_1, in watt-hours, determined from the watt-hour meter reading by the duration of the test, in hours;

P_2 is the mean power consumption, in watts, of the ventilated oven, obtained by dividing the energy consumption E_2, in watt-hours, determined from the watt-hour meter reading by the duration of the test, in hours;

V_o is the volume of the exposure chamber, in litres;

T_a is the mean ambient temperature, in kelvins;

T is the exposure temperature, in kelvins.

NOTE The calculation is based on the following assumptions.

– The density of air at ambient temperature is

$d_{Ta} = d_{20}T_{20}/T_a$ in kg/l with $T_{20} = 293$ K

– The density $d_{20} = 1{,}2045 \times 10^{-3}$ (kg/l)

– For calculation purposes a mean value is used for the specific thermal capacity at 180 °C, which is

$c_p = 1{,}022 \times 1\ 000$ (J/kg K)

– The total mass of air flow during the test period is

$M = 3\ 600\ (E_2 - E_1) / c_p(T - T_a)$ (kg)

when the air flow is heated from T_a to T and E_1 and E_2 the energy consumption in Wh derived from the Watt-hour meter readings

– The total volume of air flow during the test period is

$V = M / d_{Ta} = 3\ 600(E_2 - E_1) / c_p(T - T_a)d_{Ta}$ (l)

– The volume per hour is

$V_h = 3\ 600(P_2 - P_1) / c_p(T - T_a)d_{Ta}$ (l)

– The rate of ventilation is

$N = V_h / V_o = 3\ 600(P_2 - P_1) / c_p(T - T_a)d_{Ta}V_o = 3\ 600(P_2 - P_1)T_a / c_p(T - T_a)d_{20}T_{20}V_o$

$N = 3\ 600(P_2 - P_1)T_a / 293 \times 1{,}022 \times 1{,}205(T - T_a)V_o$

$N \sim 10{,}0 \times (P_2 - P_1)T_a / V_o(T - T_a)$

Annex B
(informative)

Examples for calculation of temperature deviation

B.1 Error of measurement

The error of measurement consists of the following elements:

- random error u_1 = ±0,5 K occurs two times, during calibration and reading of temperature sensor 1;
- random error u_2 = ±0,5 K occurs two times, during calibration and reading of temperature sensor 2;
- systematic error u_3 = ±0,1 K of temperature sensor 3;
- maximum possible temperature variation δT_V equals maximum allowable temperature fluctuation plus the maximum allowable temperature difference in a period of 3 h.

$T_{Vmax} = T_{fmax} + T_{dmax} = 1 + 1 = 2$ K

With these assumptions, the temperature deviation of the exposure temperature is given by the following relation:

$$\delta T_d = \pm\sqrt{(2u_1^{\,2} + 2u_2^{\,2} + u_3^{\,2} + \delta T_v^{\,2})}\ \text{K}$$

$$\delta T_d = \pm\sqrt{(1{,}01 + \delta T_v^{\,2})}\ \text{K}$$

The maximum possible temperature deviation, from the above equation, is

$$\delta T_d = \pm\sqrt{\{1{,}01 + 4\}}$$

$$\delta T_d \sim \pm\ 2{,}2\ \text{K}$$

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

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